Calculation of the Fire Potential Index

The Fire Potential Index (FPI) was originally developed in the late 1990s by Robert Burgan and implemented nationally at the USGS Earth Resources Observation and Science (EROS) Center (Burgan and others 1998). The Fire Potential Index (FPI) can be thought of as a numerical rating of fuel availability and ignitibility based on estimates of the proportion of dead vegetation and its dryness. In its original formulation (Burgan and others 1998), the FPI utilized the ratios of total live to dead fuel loads (lbs/ft^2) as defined by the fuel models of the 1978 National Fire Danger Rating System (NFDRS) (Deeming and others 1977). These ratios were adjusted by a Normalized Difference Vegetation Index (NDVI)-based vegetation greenness measurement to estimate seasonal changes in the live/dead ratio. It was soon discovered that NFDR fuel models, regardless of adjustment, produced similar live/dead ratios for fuel models that represent very different vegetation types. The effect was to overestimate the FPI in the eastern U.S. during summer when the vegetation is very green. The overestimation was resolved by using the historical maximum greenness to determine a maximum live ratio for every 1-km pixel in the conterminous United States.

The FPI is derived from the following inputs: maximum live vegetation ratio, relative greenness, 10-hour timelag fuel moisture, and dead fuel extinction moisture. The first three inputs are derived from satellite observations.

Relative greenness

Relative greenness (RG) is used in the FPI model to seasonally modify the estimated proportion of live and dead vegetation, i.e. the live/dead ratio. Relative greenness (Burgan and others 1993) is derived from weekly composites of the NDVI (Goward and others 1990), which is calculated from data obtained by the Advanced Very High Resolution Radiometer (AVHRR) on board the National Oceanic and Atmospheric Administration's TIROS-N series of polar-orbiting weather satellites. Historical (1990-2004) minimum and maximum NDVI data values are the basis for calculating the RG. Thus for each pixel, RG is a measure of the pixel's current "greenness" compared to its range of historical NDVI observations. Relative greenness values are scaled from 0 to 100, with low values indicating the vegetation is at or near its minimum greenness. Specifically the algorithm is:

$$RG = (ND_o - ND_{mn}) / (ND_{mx} - ND_{mn}) * 100$$

where

ND_o = highest observed NDVI value for the 1 week composite period
ND_{mn} = historical minimum NDVI value for a given pixel
ND_{mx} = historical maximum NDVI value for a given pixel

Maximum Live Ratio

Assuming there is a direct relationship between maximum NDVI and the maximum live ratio, the algorithm used to calculate the maximum live ratio map is:

$LR_{mx} = 35 + 40 * (ND_{mx} - 100)/ 80 / 100$

where

LR_{mx} = Live ratio for a given pixel when the vegetation is at maximum greenness

ND_{mx} = historical maximum NDVI for a given pixel.

NDVI values are scaled to range from a minimum of 100 by multiplying the non-negative standard fractional NDVI data values (0.0 to +1.00) by 100, then adding 100. This keeps NDVI values within the range of binary byte data (0-255). The value 35 is used as the lowest maximum percent green, even for arid areas of the West. That is, whatever amount of vegetation does exist, at least 35 percent will be green at its greenest, with the remainder being dead vegetation from previous years growth. The value 40 scales the maximum live ratio from 35 percent to 75 percent (fig. 1) as the maximum NDVI ranges from 100 to 180, the highest value recorded for the conterminous United States.

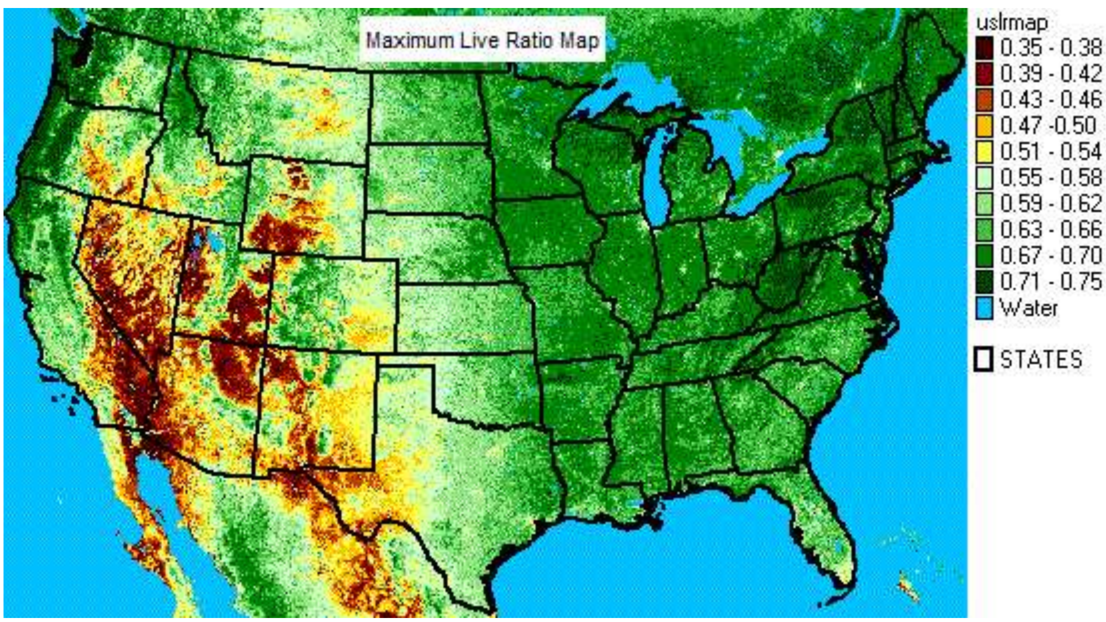

Figure 1. Maximum live ratio map for the conterminous United States.

Ten-hour timelag fuel moisture

The U.S. Department of Agriculture Forest Service's Wildland Fire Assessment System (WFAS) (http://www.wfas.net) produces 7-day 10-hour timelag fuel moisture (10-h TLFM) (Fosberg and others 1971) forecasts calculated from downscaled National Digital Forecast Database data. These gridded data are retrieved by the USGS EROS Center and used in FPI calculations.

Extinction Moisture

A dead fuel extinction moisture map (fig. 2) was prepared according to the values assigned to the various NFDRS fuel models (table 1). Dead fuel extinction moisture is defined as the moisture content in small dead fuels (0.6 to 2.5 cm diameter) at which fires will no longer spread (Rothermel 1972). Extinction moisture varies from one vegetation or fuel type to another and is generally high for moist climates such as the southeastern United States. The NFDR fuel models are described at: http://www.nwcg.gov/pms/stds/standards/nfdrs-fuel-model_v1-0.htm

Dead Fuel Extinction Moisture (%)	NFDR Fuel Model
15	A, B, F, L, T
20	C, H, U
25	G, N, Q, R, S
30	D, O, P

Table 1. Extinction moistures used in calculating the Fire Potential Index.

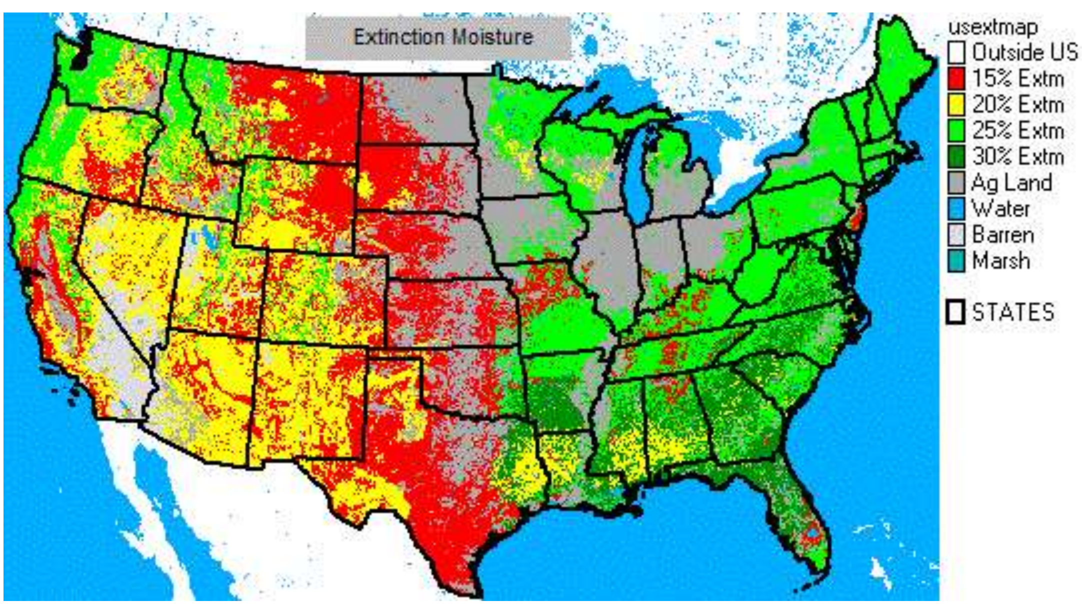

Figure 2. Extinction moistures assigned to the mapped NFDRS fuel models

The FPI Model

To estimate relative fire potential, the FPI model uses the estimated proportion of the vegetation that is live and the ratio of 10-h TLFM to the extinction moisture. Relative greenness is used to determine the proportion of the surface vegetation that is live (fig. 3).

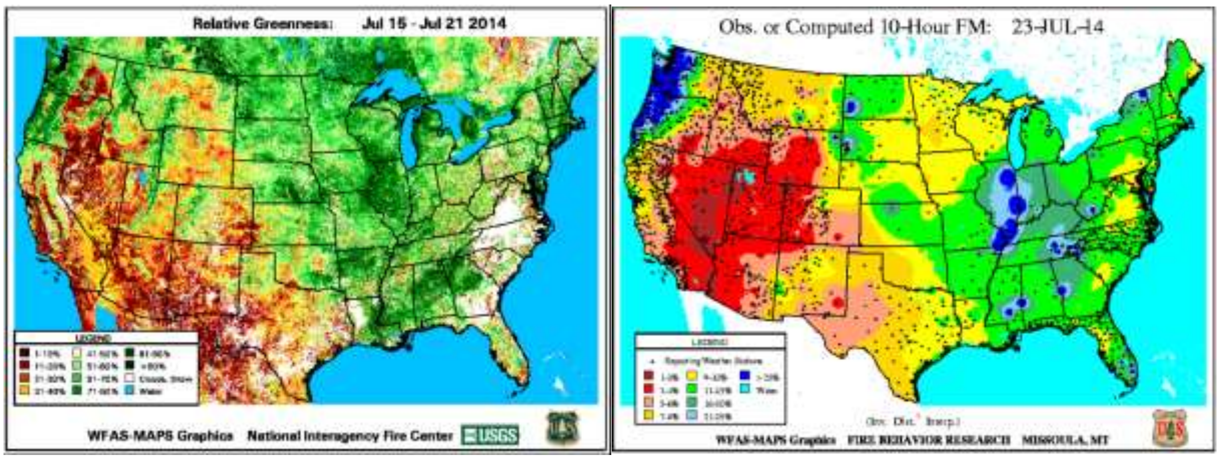

Figure 3. Relative greenness and 10-hour fuel moisture (shown here), and maximum live ratio (fig. 1) and extinction moisture (fig. 2) are inputs to the FPI map calculation.

The FPI index is scaled from 0-100. The specific process for each pixel is to obtain the following data: dead fuel extinction moisture, RG, 10-h TLFM, and maximum live ratio and perform the following calculations:

Convert relative greenness to a fractional value

(1) $RG_f = RG/100$

The relative greenness fraction is used to determine the current live fuel ratio (LR) for the pixel.

(2) $LR = RG_f * LR_{mx} / 100$

Ten-hour fuel moisture (percent of dry weight, table 1) is normalized to the moisture of extinction (MX_d) for the fuel model to produce a fractional 10-hour moisture (TN_f) that is scaled the same as fractional relative greenness (0-1). The 10-h TLFM is limited to a minimum of 2 percent, thus subtracting 2 from both the 10-h TLFM and the extinction moisture allows TN_f to reach zero when the 10-h TLFM is at its minimum value and provides a convenient method of scaling the FPI from 0 to 100. The TN_f is smoothed near its minimum and maximum limits (0 and 1) to avoid discontinuities.

(3) $TN_f = (FM_{10} - 2)/(MX_d - 2)$

where

TN_f = fractional 10-hour fuel moisture
FM_{10} = 10-hour moisture (percent)
MX_d = dead fuel extinction moisture (percent)

The FPI calculation is performed only if the pixel represents a valid fuel model, i.e. not agriculture, barren, etc. The LR defines the proportion of live vegetation, and inversely the proportion of dead vegetation (proportion dead equals 1 minus proportion live). Because live vegetation is green, it is assumed to have high moisture content, thus reducing fire potential. The dead vegetation moisture content, as calculated from current weather data, is relatively low -- less than 30 percent. Thus the FPI can be thought of as a “dryness” fraction multiplied by a “deadness” fraction.

(4) $FPI = (1 - TN_f) * (1 - LR) * 100$

Equation (4) produces FPI values that range from 0 to 100. The FPI will equal 0 when the TN_f is 1 (the dead fuel moisture equals the moisture of extinction) or the live ratio value is 1 (the vegetation is fully green). The FPI will attain a value of 100 if the live ratio is 0 (all the vegetation is cured) and the 10-h TLFM is at its minimum value of 2 percent.

In the fuel model data, pixels that indicate agricultural lands, barren land, marsh or water; and clouds, Canada or Mexico, are assigned FPI values ranging from 249 to 254. The resulting output is a gridded raster file that can be analyzed using a GIS, and displayed. Figure 4 illustrates the relationship between the FPI map and the standard NFDRS map for July 23, 2014.

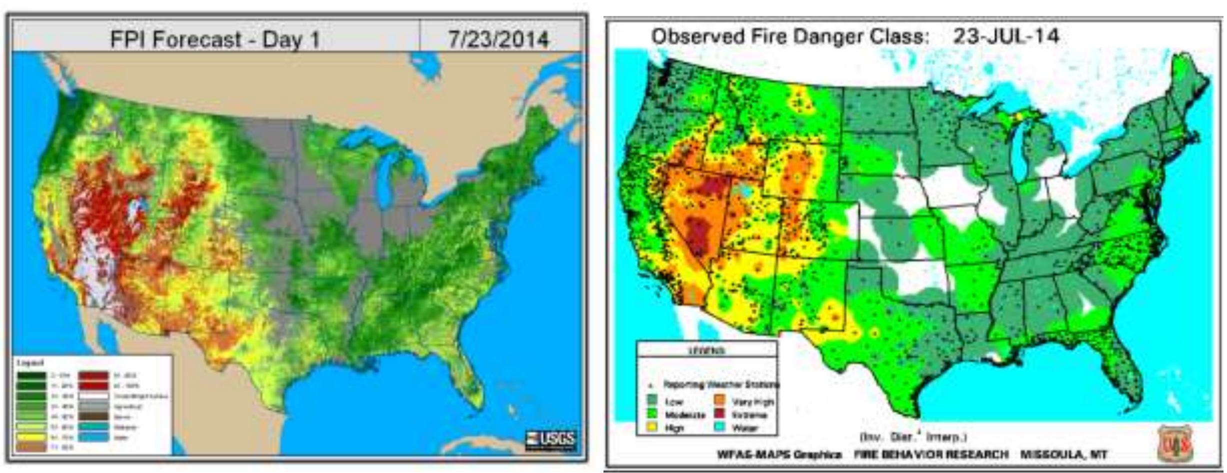

Figure 4. A fire potential index map compared with the standard NFDRS map.

References

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